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REVIEW ARTICLE

Air Pollution Threatens the Health of Children in China

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ABSTRACT

CONTEXT. China's rapid economic development has come at the cost of severe environmental degradation, most notably from coal combustion. Outdoor air pollution is associated with >300 000 deaths, 20 million cases of respiratory illness, and a health cost of >500 billion renminbi (>3% of gross domestic product) annually. The young are particularly susceptible to air pollution, yet there has been only limited recognition of its effects on children's health and development.

DATA SOURCES/DATA EXTRACTION. To fill this gap, we reviewed relevant published environmental studies, biomedical and molecular/epidemiologic research, and economic and policy analyses.

RESULTS. China relies on coal for ~70% to 75% of its energy needs, consuming 1.9 billion tons of coal each year. In addition to CO_2, the major greenhouse gas, coal burning in China emits vast quantities of particulate matter, polycyclic aromatic hydrocarbons, sulfur dioxide, arsenic, and mercury. Automobiles emit nitrogen dioxide and benzene in addition to particulate matter and polycyclic aromatic hydrocarbons. Seventy percent of Chinese households burn coal or biomass for cooking and heating, which contaminates indoor air. Adverse effects of combustion-related air pollution include reduced fetal and child growth, pulmonary disease including asthma, developmental impairment, and increased risk of cancer. A prospective molecular epidemiologic study of newborns in Chongqing has demonstrated direct benefits to children's health and development from the elimination of a coal-burning plant.

CONCLUSIONS. Recognition of the full health and economic cost of air pollution to Chinese children and the benefits of pollution reduction should spur increased use of renewable energy, energy efficiency, and clean-fuel vehicles. This is a necessary investment for China's future. *Pediatrics* 2008;122:620–628

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Key Words
air pollution, China, children, polycyclic aromatic hydrocarbons, DNA adducts

Abbreviations
PM—particulate matter
PAH—polycyclic aromatic hydrocarbon
SO_2—sulfur dioxide
NO_2—nitrogen dioxide
CO_2—carbon dioxide
B[a]P—benzo[a]pyrene
WHO—World Health Organization
CCCEH—Columbia Center for Children's Environmental Health
GDP—gross domestic product

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ALONG WITH DRAMATIC economic benefits, China's rapid development has brought severe environmental degradation, notably air pollution from coal burning and traffic that sullies the air of its cities and countryside. The Chinese government has recognized that air pollution is a serious problem and has implemented various corrective measures. Nonetheless, a continuation of present trends in fossil-fuel burning could cause environmental damage on such a scale that the health of China's children, as well as its future economic development, could be severely impaired.[1]

Although the effects of air pollution on cardiovascular and lung disease in adults in China have been recognized, there is far less awareness of the impacts of air pollution on children's health.[2–4] An understanding of the enormous burden that air pollution places on the health of Chinese children should spur needed action to protect this vulnerable population.

AIR POLLUTION LEVELS AND SOURCES

Outdoor Air Pollution

As a consequence of combustion of fossil fuel to meet its energy and transportation needs, China produces vast quantities of ambient air pollution, including particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), heavy metals, and carbon dioxide (CO_2). Combustion of coal is the principal source of China's outdoor air pollution.[5] China's vast industrial network and power-plant system rely on coal for ~70% to 75% of their energy needs compared with 14%, 22%, and 53% for Japan, the United States, and India, respectively.[6,7] Coal-fired power plants in China currently produce nearly 70% to 75% of the country's electricity.[8] The majority of new power plants in China are designed to burn coal. China burned ~1.9 billion tons of coal in 2005, which was a 12% increase from 2004. If such consumption practices continue, China alone could negate the progress of other countries that are reducing dirty coal emissions and phasing in cleaner fuel alternatives.

In addition to being the major source of CO_2, the most significant human cause of global warming, coal burning emits PM, PAHs (such as benzo[a]pyrene [B[a]P]), SO_2, arsenic, and mercury. In 2003, the annual average values of PM_{10} in the ambient air of 53% of 341 monitored Chinese cities exceeded the concurrent Chinese standard of 100 $\mu g/m^3$.[1] Twenty-one percent of the cities had PM_{10} levels of >150 $\mu g/m^3$.[1] Approximately 25% exceeded the concurrent Chinese SO_2 standard of 60 $\mu g/m^3$.[1] Although the number of Chinese cities meeting SO_2 standards has increased since the implementation of acid rain–control programs in the late 1990s, the country's overall SO_2 emissions in 2005 were 28% higher than they were in 2000.[1] The current World Health Organization (WHO) annual average standards for PM_{10} and SO_2 are 20 $\mu g/m^3$ and 60 $\mu g/m$, respectively.[9] The corresponding US standards are 50 $\mu g/m^3$ for PM_{10} and 50 $\mu g/m^3$ for SO_2.[10] Thus, the annual average PM_{10} value for the majority of 341 Chinese cities exceeded both US and WHO PM_{10} standards, and ~25% of 341 Chinese cities exceeded both US and WHO standards for SO_2 levels. For comparison, at 1190 monitoring sites in the United States in 2005, the annual average value of PM_{10} was ~24 $\mu g/m^3$,[11,12] and the annual average SO_2 concentration at 219 monitoring sites was between 6.5 and 13 $\mu g/m^3$.[13] China's heavy use of coal for energy and industry and lack of emissions-control equipment largely explain the much higher levels of PM_{10} and SO_2 in Chinese air.[14]

Although larger particles found in natural dust are generally of less concern in terms of toxicity than the smaller, deeply respirable particles emitted by human combustion sources, annual desert dust storms in the spring exacerbate the effects of anthropogenic air pollution in the northeast of China and several neighboring countries. The 24-hour PM_{10} concentration in Beijing reached 898 $\mu g/m^3$ during a dust- storm period in 2000 compared with the daily average concentration of 190 $\mu g/m^3$ during that year.[15] Both values exceeded China's national ambient air quality standard of 150 $\mu g/m^3$ for 24-hour PM_{10}.[15] Higher levels of PM_{10} as a result of these annual dust storms have also been reported in Mongolia, Russia, Japan, and Korea.[16]

China's power plants and industry emit 600 tons of mercury into the atmosphere each year, making China the source of nearly one quarter of the world's anthropogenic emissions of mercury.[17] In contrast, the United States produced 120 tons of atmospheric mercury in 1999.[17] Disproportionately high use of coal in heavy industry in China's central provinces such as Shaanxi, Guizhou, Henan, and Sichuan has resulted in these regions having the highest emissions of mercury.[7] Coal combustion is responsible for an estimated 46% of Chongqing's total mercury emissions.[18]

In urban areas, automobiles are a major source of air pollution. Motor vehicles in China represent another significant source of outdoor air pollutants, including NO_2 and benzene as well as PM and PAHs. Personal vehicle ownership has increased dramatically among the growing middle class.[19] In China, privately owned cars were almost nonexistent before 1978, but their total number reached >29 million by the end of 2006.[20] Ownership of motorcycles, which have less-stringent emissions standards than automobiles and represent an inexpensive alternative, is also expected to increase from 59.29 million in 2003 to 192 million by 2020.[21,22] Motorcycles are particularly appealing for those living in midsized cities with poor public transportation.[21,22] Growing vehicular emissions in urban centers threaten to derail progress from industrial emissions-control programs.[19] On a positive note, the Chinese government banned the selling of leaded gasoline in 2000. Before the ban, a large percentage of newborns in urban centers such as Shanghai had blood lead levels in excess of 10 $\mu g/dL$ and were at high risk for developing neuropsychological deficiencies.[23] Studies performed after the 2000 ban showed that children's blood levels have decreased significantly, especially in younger children who have had less exposure to atmospheric lead.[24] The successful phase-out of leaded gasoline in 2000 demonstrates that focused political action can rapidly reduce threats to public health from air pollution.

In 2001, the annual average concentration of NO_2 in the ambient air of 95 Chinese cities was 35.44 $\mu g/m^3$ (range: 11–71 $\mu g/m^3$).[3] This concentration did not exceed the Chinese standard (80 $\mu g/m^3$) or the current WHO (40 $\mu g/m^3$) or US standards (100 $\mu g/m^3$).[3,25] However, the annual NO_2 concentration in Chinese cities (35.44 $\mu g/m^3$) was 75% higher than that in urban areas in the United States in 2005 (20 $\mu g/m^3$).[25] NO_2 emissions are increasing rapidly with the rise in motor vehicle ownership in China. The World Bank in 1997 estimated that China's NO_2 emissions would rise from 965 000 tons in 1993 to between 3 094 000 and 22 305 000 tons by 2020, depending on the rate of motor vehicle ownership and the development of public transportation.[21]

Indoor Air Pollution

Indoor air pollution originating from cooking and heating represents another major environmental exposure that affects the health of children in China. Seventy percent of Chinese households burn coal or biomass for domestic energy requirements.[26] Natural gas used for cooking is becoming popular in the areas where economic conditions have improved dramatically. Although more-prosperous urban residents can afford clean natural gas for their homes, most rural households in China use coal for cooking, heating, and electricity.[27,28] The combustion of coal and biomass in poorly ventilated homes exposes children to high levels of sulfur oxides, nitric oxides, respirable PM, PAHs, metals, and carbon monoxide. Because of its warmer climate, there is far less coal burning for residential heating in southern China than in the north. Provinces with homes that rely on coal as the principal source of fuel for domestic needs have indoor SO_2 levels that range from 210 to 1860 $\mu g/m^3$, which are substantially higher than the levels recorded in homes that burned biomass. However, homes that depend on biomass for cooking and heating had comparatively higher levels of PM_4 (351 to >700 $\mu g/m^3$) than homes that used coal (187 to 352 $\mu g/m^3$).[26] Irrespective of fuel type used, concentrations of both SO_2 and PM pollutants were highest during the winter months when fuel consumption was greatest, whereas concentrations were lowest during the spring when heating requirements were lower.[26] Indoor concentrations of PM_4 and SO_2 were in excess of international standards regardless of fuel type used in both the winter and spring.[26]

In the 1980s the Chinese government implemented the National Improved Stove Program to install energy-efficient biomass and coal stoves in rural Chinese homes; however, the coal stoves often lacked effective ventilation mechanisms.[29] The Chinese government is currently encouraging the use of higher-quality refined coal and alternative fuels.[30] Nevertheless, until rural residents are able to afford alternative fuels for domestic energy use on a large scale, indoor air pollution will continue to threaten children's health in China.

Affecting an estimated 200 million children in China, secondhand smoke represents a significant source of indoor air pollution for Chinese children.[31] Chinese children living in homes with parents who smoke had lower pulmonary function than their peers with nonsmoking parents.[32] In addition, reductions in birth weight have been found in Chinese children exposed to secondhand smoke in utero.[33] Finally, many cities are building new residential buildings with nonsustainable materials that expose residents to toxic chemicals.

HEALTH RISKS TO CHILDREN FROM COAL-COMBUSTION BYPRODUCTS AND MOTOR VEHICLE EMISSIONS

Susceptibility of the Young

Although air pollution has detrimental effects on all members of a population, the very young are at particular risk. Experimental and human evidence indicates that the fetus and neonate are more susceptible than adults to carcinogens as diverse as PAHs, nitrosamines, pesticides, tobacco smoke, air pollution, and radiation.[3,19,23,24,34–36] In addition to increasing the risk of childhood cancer, in utero and neonatal exposure to carcinogens can raise the risk of cancer later in life and to a greater degree than exposure during the adult years.[37–39] Susceptibility of the fetus and child to developmental toxicants such as lead, polychlorinated biphenyls, PAHs, and diverse respiratory toxicants has also been demonstrated.[40] The increased vulnerability of fetuses and children to environmental pollutants stems from their greater absorption and slower clearance of toxicants and decreased ability to detoxify exogenous chemicals or to repair damaged DNA.[40,41] Environmental toxicants are transferred across the placenta to varying degrees. Moreover, the fetus lacks a mature blood-brain barrier, which does not completely form until 6 months after birth.[41] Young children remain particularly susceptible to developmental toxicants for several years after birth, because the brain continues to develop postnatally with the continued growth of glial cells and myelination of axons.[42,43] Lung development continues through a child's sixth to eighth year of life.[40,41,44] Infants have been shown to be more susceptible to chronic respiratory effects and mortality related to air pollution.[45,46] Moreover, fetal and childhood exposure to carcinogens, respiratory toxicants, or neurotoxicants can increase risk of disease in adulthood, because the "initiated" cells and tissues have the opportunity to develop to malignancy or acquire additional damage over the next decades of life.[41,47]

Adverse Birth Outcomes

Many studies have shown that combustion-related air pollution is associated with reduced fetal growth. In humans, associations between PAHs or PAH-DNA damage and fetal growth reduction have been reported in a number of studies.[48–52] In New York City, high PAH exposure during pregnancy was associated with decreased birth weight and head circumference among black infants.[51] A study in Poland also showed that prenatal PAH exposure was a risk factor for reduced fetal growth.[48] In the Czech Republic, ambient PAHs significantly increased the risk of intrauterine growth retardation.[49] White newborns in Poland who had higher leukocyte PAH-DNA adduct levels in umbilical cord blood (a measure of PAH exposure) had significantly reduced birth weight, length, and head circumference.[50] As will be discussed, a recent study in China found decreased head circumference in newborns who had elevated PAH-DNA adducts in cord blood.[53] Reduced fetal growth is associated with a higher risk of developmental and health problems in childhood.[51]

Pulmonary Disease

The health effects of inhalation exposure to the byproducts of energy-related combustion are currently manifesting in Chinese children as indicated by rising levels of pulmonary disorders such as childhood asthma. The prevalence of childhood asthma among urban children rose by 64% during the 1990s to 1.97% nationally.[54] In bigger cities, where the air quality is worse and awareness of the ailment is higher, this figure more than doubled. Most affected was Chongqing, one of the fastest growing metropolises in China, where the prevalence among children younger than 14 years was 4.63%.[54] These statistics may be underreporting the true numbers of asthmatic children, because cultural preferences make it more likely for boys to receive medical care for their asthma than girls.[54] The causal relationship between coal-burning emissions and increasing prevalence of asthma is supported by higher incidences of asthma-related symptoms and other pulmonary dysfunctions during the winter months when coal consumption is at its peak.[55,56] For example, measures of lung function (forced expiratory volume, forced vital capacity, and peak expiratory flow) in children were shown to decline during the winter months when coal combustion is highest.[55] A study in New York City by the Columbia Center for Children's Environmental Health (CCCEH) has shown that prenatal exposure to PAHs combined with postnatal secondhand smoke are associated with respiratory symptoms and risk of asthma in exposed children.[57] Studies conducted in China by US academic institutions and the US Environmental Protection Agency indicated that high levels of both indoor and outdoor air pollution from coal burning increase risk of respiratory morbidity such as cough with phlegm, wheeze, asthma, and bronchitis in Chinese children.[56,58]

Pollutants related to automobile emissions, including nitrogen oxides, have already impacted the health of children living in Chinese urban centers.[59] Chronic exposure to nitrogen oxide, primarily from automobile emissions, has been linked to decreased pulmonary function in Chinese children.[60] Decreased lung function during early development is associated with poor pulmonary function throughout adult life.[47]

The high levels of indoor air pollution in Chinese households have also been linked to an increased incidence of asthma in children.[27] Research in Beijing has indicated that the indoor environment can be dangerous for asthmatic children because of the potential of combined exposure to particulates from cooking/heating, tobacco smoke, indoor molds and fungi, and allergens from dogs, cats, and vermin such as rats and cockroaches.[61]

Thus, many studies have shown that both outdoor and indoor air pollution from fuel burning are risk factors for respiratory illness in children. Moreover, outdoor air pollution penetrates readily into the indoor environment, which compounds the effects of pollution from cooking, heating, and tobacco smoking by adults in the home.[62]

Cancer

There have been no studies of air pollution and childhood cancer in China. However, several lines of evidence suggest that exposure to carcinogenic air pollutants, such as PAHs from coal combustion, have contributed to the increasing rates of lung cancer in Chinese adults. Experimental studies on bacteria and mice exposed to air pollution at multiple sites in Shanghai demonstrated genotoxic damage that was especially severe during the winter months when coal use is at its peak.[63] Moreover, research in Shengyang showed high levels of cytogenetic damage in women living in industrial areas, which could explain the unusually high incidence of lung cancer among the female population in northern China.[64] A study in New York City found a significant association between prenatal PAH exposure and chromosomal aberrations in umbilical cord blood, which signals a potentially increased risk of cancer.[65] Inhalation exposure to benzene, a known leukemogen present in automobile emissions, may also contribute to childhood cancer.[66,67] Moreover, Chinese coal contains high concentrations of arsenic, a known carcinogen that is released after combustion. In some areas of China, as many as 60% of people <30 years old suffer from chronic arsenicism as a result of long-term exposure to arsenic-rich coal combustion and, hence, are at greater risk for developing cancer.[68,69]

Neurodevelopmental Effects

Coal burning in China results in substantial deposition of mercury into fishable waters. Prenatal mercury exposure from maternal consumption of fish from waters contaminated by mercury has been associated with developmental deficits in children in the United States and elsewhere.[70,71] PAHs in air pollution have also been linked to developmental impairment. Children in New York City who had high prenatal exposure to airborne PAHs had significantly lower test scores at age 3 on the Bayley test for cognitive development and significantly increased odds of developmental delay at age 3, after controlling for other exposures and risk factors.[72] As will be discussed, similar adverse effects on development have been seen in Chinese children.

BENEFITS OF REDUCING EXPOSURE TO COAL-BURNING EMISSIONS IN CHINESE CHILDREN: A CASE STUDY

Since 2001, the CCCEH and the Chongqing Children's Hospital have been investigating health benefits to children from the elimination of a coal-burning power plant in Tongliang County, Chongqing. A collaborative effort with the Chongqing municipality, Chongqing Institute of Environmental Sciences, the Chongqing Center of Environmental Monitoring, the Chongqing Municipal Economic Commission, the Desert Research Institute of the Nevada System of Higher Education, and the Natural Resources Defense Council, the research combines molecular epidemiologic techniques with air-monitoring data, geographic information-system analysis, and clinical neonatal and pediatric assessments.

With a population of >32 000 000 people, the municipality of Chongqing is one of the largest and most heavily polluted cities in China, largely as a result of coal combustion by power plants and industry. The county of Tongliang in Chongqing municipality, with a population of >800 000 people, is situated in a small basin ~3 km in diameter and, thus, subject to inversions that trap polluted air. Before 2004, a coal-fired power plant located just south of Tongliang's center operated 6 months each year (from December 1 to May 31) to compensate for insufficient hydroelectric power during those months. The plant was the principal source of local air pollution, because by 1995 nearly all domestic heating and cooking units had been converted to natural gas and in 2001 motor vehicles were not yet a major source of air pollution. The plant burned ~25 000 tons of high sulfur coal during each 6-month period of operation and was not equipped with modern pollution-reduction technology. In May 2004, after assessing the potential social and economic impact, the Tongliang government shut down the power plant permanently to enforce the central government's emissions standards and protect the public's health.

Air-monitoring data collected by the research team in 2002 before the power plant shut down showed that ambient concentrations of the representative PAH, B[a]P, in Tongliang county were >3 times higher during the power plant's operational period than during the nonoperational period.[73] The average ambient air concentration of B[a]P was 15 ng/m³ compared with that in New York City (0.5 ng/m³).[73] The average ambient $PM_{2.5}$ levels in 2002 in Tongliang were >5 times higher than the annual $PM_{2.5}$ US national ambient air quality standard of 15 μg/m³.[73] Marked seasonal variation in air pollution (PAHs and PM) was attributable, in large part, to power-plant emissions.

Three successive cohorts of mothers and newborns have been enrolled: the first in 2002 before the Tongliang power plant was closed down in 2004; the second in 2005, 1 year after the closure; and the third in 2007, 3 years after the shutdown. The 3 cohorts of mothers and children are being followed to compare their exposure to air pollutants and the children's health and development over the first several years of childhood. Between March 1 and June 30, 2002, 2004, and 2005, respectively, the 3 cohorts, each consisting of 150 mother/child pairs, were enrolled before delivery.[53] The women gave birth at the Tongliang County Hospital, Tongliang Traditional Chinese Medicine Hospital, Tongliang Maternal Children Health Hospital, and Bachuan Hospital. Eligibility criteria included current nonsmoking status, ≥20 years of age, and residence within 2.5 km of the Tongliang power plant. All subjects gave informed written consent. A questionnaire administered by a trained interviewer after delivery elicited sociodemographic information, lifetime residential history, history of active and passive smoking occupational exposure, medication information, alcohol use during pregnancy, and dietary exposure to PAHs. Umbilical cord blood was collected at delivery. As a proxy for PAH-DNA adducts, B[a]P-DNA adducts were analyzed in extracted white blood cell DNA by using a modified high-performance liquid chromatography–fluorescence method,[74] which detects B[a]P tetrols. Birth weight, birth length, and head circumference were measured immediately after parturition. Information related to the pregnancy and delivery was abstracted from the mothers' and infants' medical charts. Outcomes analyzed in this study included birth weight, length, and head circumference, as well as child weight, length, and head circumference at 18, 24, and 30 months of age. Neurobehavioral development (Gesell test at age 2, Wechsler Intelligence Scale for children at age 5) and respiratory symptoms have been collected during fellow-up of the cohorts.

In the first cohort, newborns who were exposed in utero to emissions from the coal-burning power plant had significantly higher levels of PAH-DNA adducts in their cord blood than newborns in New York City, which is consistent with the higher levels of PAHs in Tongliang noted earlier.[75] The Chinese newborns with higher levels of PAH-DNA adducts had a smaller average head circumference at birth and a lower physical growth rate in childhood.[53] In addition, they performed significantly less well on tests of cognitive development at age 2.[53]

Comparison of the first cohort with the second cohort of 150 mothers and 150 newborns has provided evidence of a clear improvement in air quality, biomarker levels, and pregnancy outcomes. Levels of airborne PAHs and other pollutants measured in 2005 were significantly reduced from the 2002 levels, as were the levels of PAH-DNA adducts measured in umbilical cord blood. Birth outcomes in the 2005 cohort were also generally more favorable, and there was no longer an observable relationship between PAH-DNA adducts and reduced birth head circumference such as was seen in the first cohort.

Subsequent follow-up of the cohorts in 2002 to examine the relationship between PAH-DNA adduct levels and neurobehavioral development (Gesell Test at age 2) revealed a significant association between elevated adduct levels and decreased motor area, language area and average developmental quotients.[76]

The significant associations between adduct levels and decreased motor area developmental quotient and average developmental quotient found in 2002 were not observed in the 2005 cohort, although the nature of the relationship did not change.[77]

The ongoing research between CCCEH and research partners in Chongqing provides a valuable opportunity to measure and quantify the health benefits of an observed reduction in ambient levels of specific pollutants. The results have thus far shown immediate benefits of an intervention to eliminate coal-burning emissions. A comprehensive assessment of the benefits of intervention will necessarily consider the fact that the early-occurring health and developmental effects may themselves persist into adulthood or otherwise have long-term consequences for adult health. Moreover, on the basis of the observed changes in Chongqing, it will be possible to extrapolate the results across China.

ESTIMATION OF HEALTH AND ECONOMIC COSTS

The human and economic costs of China's air pollution are unquestionably huge. In 2003 the Chinese Academy of Environmental Planning estimated that 300 000 people die every year as a result of ambient air pollution, mainly from heart disease or lung cancer.[78] Higher numbers have been reported more recently.[78] The Organization for Economic Co-operation and Development estimates that China's air pollution currently causes 20 million cases of respiratory illness annually and could result in 600 000 premature deaths in urban areas by 2020.[29] The estimated health costs associated with outdoor air pollution in China range from 157.3 billion renminbi (1.16% of the 2003 gross domestic product [GDP]) to 519.9 billion renminbi (3.8% of the 2003 GDP).[1] Although no studies have estimated the full health and economic costs of air pollution-related illness in children, the benefits of reducing air pollution on respiratory illness in children have been estimated at 3.5 billion US dollars over the period 2002–2011.[79] China's environmental pollution clearly carries with it an enormous cost in human and economic terms.

SOLUTIONS

Investments in renewable-energy projects, energy-use efficiency, and clean-fuel vehicles hold great potential for reducing air pollution and ensuring long-term, sustainable economic development in China. In recent years, China has made considerable progress in developing its renewable-energy market and creating economic incentives for increased energy-efficiency and fuel-economy standards. With respect to renewable-energy policy, the Chinese government has committed to a target of 15% renewable in the national energy mix by 2020.[80] On January 1, 2006, China's Renewable Energy Law took effect. This law stipulates that various levels of the government should encourage and support the development and use of renewable energy, including measures that allow grid connection and cost sharing for renewable electricity. As of 2005, the total installed wind-power capacity in China reached 1.27 GW, and China plans to expand wind-power capacity to 30 GW by 2020.[81] Solar and geothermal energy development have seen rapid growth in China as well. However, advanced renewable-energy technologies are currently more expensive than conventional coal applications, which is a major barrier to more widespread use of renewable energy. Therefore, it is essential that the government provide financial incentives to help renewable-energy technologies penetrate the market.

China's overall energy-use efficiency is only ~34%, which is 10 percentage points lower than that of most industrialized countries.[82] To generate 1 unit of GDP, China consumes 3 times more energy than the United States.[82] In 2005 the Chinese government announced the goal of reducing energy consumption per unit of GDP by 20% by 2010 and has since embarked on a series of initiatives. One initiative targets the country's top 1000 energy-consuming enterprises for cuts in energy consumption.[83] China has also experimented with specialized loan programs to assist factories in defraying the costs of upgrading equipment.[14] The demand-side management of energy consumption, an effective efficiency strategy practiced successfully in many US states, is now being promoted by China's National Development and Reform Commission with technical assistance from the Natural Resources Defense Council and the Energy Foundation, 2 American nonprofit organizations.[80] Pilot DSM programs implemented in several Chinese provinces and municipalities have successfully improved energy efficiency, decreased peak consumption, and reduced the need for additional coal power plant construction. It was estimated that demand-side management programs could meet up to half of China's forecasted power growth over the next decade, which is equivalent to avoiding the construction of 500 to 700 large coal power plants.[84] Buildings are an important category for energy conservation. Undergoing an unprecedented construction boom, China can cut pollution by improving energy efficiency and overall environmental performance in the construction and operation sectors.

In large cities such as Beijing, Shanghai, and Guangzhou, automobile emissions contribute >60% of total urban air pollution.[85] Since 2000, to cope with worsening urban traffic and air pollution from motor vehicles, China has been actively developing technologies for cleaner vehicles including electric, hybrid, and fuel-cell vehicles.[86] Vehicle-emission and fuel-economy standards are also gradually becoming more stringent. However, the expansion of car ownership has been so rapid that air pollution in most Chinese cities remains severe, demanding more aggressive efforts.

With respect to regulation and enforcement, the Air Pollution Prevention and Control Law and the pollution levy system of the Environmental Protection Law represent China's principal legislative and enforcement mechanisms for regulating air pollution.[87] The pollution levy system was designed to control emissions by fining industries in excess of standards. However, low penalty fees have stymied its effectiveness, because upgrading equipment to meet standards has often been more expensive for heavy polluters than paying the penalty fee.

Environmental compliance has been weak in China, where a culture of noncompliance with environmental laws is still the norm.[18] As of 2004, there were only ~50 000 inspectors in China distributed among 3000 environmental inspection agencies. Because the inspectors are typically supervised by local governments, they are subject to local pressures.[18] Commonly cited challenges for local inspection officials include enterprises operating pollution-abatement equipment only when inspectors visit, insufficient staffing, pressure on local governments to enforce regulations more leniently in the case of important local industries, and a lack of support from local officials of other departments.[18] To address this problem, China experimented with a Green-Watch program in 2 cities between 1999 and 2000 with support from the World Bank.[88] This program was incentive-based and relied on a transparent system of disseminating information on polluters to the media and public. In 2005, China's Environmental Protection Administration requested that all provincial and municipal environmental protection bureaus begin implementing such a program by 2006.[89] If effectively conducted across China, the program should improve pollution abatement, as similar models from other Asian countries have demonstrated.[88]

CONCLUSIONS

China's economic revolution has not been without substantial cost to its environment and the health of its people, particularly children, who are most vulnerable. Heavy reliance on coal and policies focused principally on economic development have left China facing rising rates of childhood asthma, neurodevelopmental disorders in children, cardiovascular disease, and cancer. In addition, increasing private automobile ownership has dramatically increased air pollution in China's urban centers.

China has successfully implemented interventions such as the phasing out of leaded gasoline, which rapidly reduced blood lead levels in children. As demonstrated by the CCCEH/China study in the Chongqing municipality, government action to reduce coal-fired power-plant emissions has resulted in direct and immediate health benefits to children—benefits that will accrue over their entire lifetime. By enacting broad policies to control coal burning and reduce automobile emissions and by adopting sustainable energy alternatives, China will be able to better protect its children and its future.

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RIGHTS OF CHIMPS

"Spain's parliament recently passed a resolution granting legal rights to apes. Reaction has been mixed. Peter Singer, a Princeton University bioethics professor and animal liberation activist, declared the vote to be of 'world historical significance.' The comedian Stephen Colbert—flashing a photo of a performing chimpanzee—insisted that the new law had better not give apes 'the right to not wear a tuxedo and roller skates.' In fact, it will likely do just that. A nonbonding resolution in Spain, which the Parliament now has to flesh out with more specific laws, allows apes to be kept in zoos but not used in circuses or other kinds of performances. It calls for banning research that harms apes. With the resolution, Spain becomes the world leader in protecting the rights of apes, but perhaps not for long. Austrian animal rights activists are fighting to have a chimp named Matthew Hiasl Pan declared a person. They have lost so far, but are appealing to the European Court of Human Rights."

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